漫談不斷電電源供應器 (UPS) Energy Star

隨著經濟的發展，科技的進步，人們的需求，生活環境的變遷及傳統能源礦產的日漸減少，讓世界大部分的國家努力追求綠能的發展，在發展中，發覺許多電子設備的能耗統計數據不斷增加，已越來越受到人們及各國的關心。7 年前，美國數據中心總耗電量約為 610 億千瓦，而到 2011 年，總耗電量成長已超過 1000 億千瓦，造成電力成本不斷增高，設備的效能受到了嚴峻挑戰. 不斷電電源供應器 (UPS)在數據中耗電量約接近 20%，且不斷電電源供應器 (UPS)設備是 24 小時在線工作，所以如果能夠改善其供電效率，就可以大大降低電力的消耗，所以不斷電電源供應器 (UPS)製造商不斷研發新的設計，以降低能耗。

目前有些國家，針對不斷電電源供應器 (UPS)能耗制定了相關標準，舉例如下:

美國: Energy Star
加拿大: CEC
歐盟: ErP

本文將針對美國的 UPS Energy Star 標準進行探討. 2010 年美國 EPA 開始制定新的能源之星計畫，來將不斷電電源供應器 (UPS)納入其中，原希望 2010 年底完成，但因納入產品較多，所以延遲至 2012 年中才完成實施。

US Energy star 雖然不是強制性，但因 US 市場的廣大及使用者的接受度大，所以廠商自願申請詢問度頗高。

- US UPS Energy Star 參考標準如下:

1) For Ac-output UPSs, International Electrotechnical Commission (IEC) standard:

a) IEC 62040-3:2011, Ed. 2.0, *Uninterruptible power systems (UPS) - Part 3: Method of specifying the performance and test requirements*, Section J.2.

2) For Dc-output UPSs/Rectifiers, Alliance for Telecommunications Industry Solutions (ATIS) standards:

a) ATIS-0600015.2009, *Energy Efficiency for Telecommunication Equipment: Methodology for Measurement and Reporting – General Requirements*; and

b) ATIS-0600015.04.2010, *Energy Efficiency for Telecommunication Equipment: Methodology for Measurement and Reporting DC Power Plant – Rectifier Requirements*.

- US UPS Energy Star 適用範圍如下:

1) 消費性 UPS 意圖保護桌上型電腦和有關的週邊，和/或家庭娛樂設備(例如電視，機上盒，DVRs，藍光和 DVD 播放器)；
2) 商業性 UPS 意圖保護小型商業和分公司訊息和通信技術設備(例如伺服器，網路轉接和路由器)，和 小存儲陣列；
3) 數據中心 UPS 意圖保護大型裝置訊息和通訊技術設備(例如企業伺服器，網路設備和大型貯存)陣列； 並且，
4) 電信 DC 輸出 UPS /整流器意圖保護電信網路系統位在一個中心站內或者在一無線遙控/ 蜂窩狀站

- US UPS Energy Star 排除範圍如下:

1) 電腦內部的的產品或另一個最終端用途負載(例如，電池補充內部的電源或者為數據機或安全系統電備用為數據機，候補的內部的電源或者電池，等等)；
2) 工業 UPS 規定設計在保護重要控制，生產，或者生產過程或者運作；

3) 實用UPS設計作為電子傳輸和銷售系統使用 (例如 電支局或者UPS 附近水準) ;
4) 有線電視(CATV) UPS 設計作為電纜信號分配系統和直接或者間接連結到它自己是.電纜可能是同軸的電纜(金屬電線) ,光纖，或者無線(例如，“Wi-Fi”);

- UPS 操作模式區分:

1) 正常模式(Normal mode)：UPS 在下列條件下獲得的穩定工作模式：
   a) AC 輸入供應在要求誤差內提供給 UPS。
   b) 能量存儲系統維持已充電或再被充電。
   c) 負荷是在 UPS 的額定值內。
   d) 支路是可提供和在指定的誤差內(如果適用)

2) 儲存能量模式(Stored Energy Mode): UPS 在下列條件下獲得的穩定工作模式：
   a) AC 輸入功率被斷開或超出要求的誤差。
   b) 全部功率由能量儲存系統來傳輸或就 DRUPS 而論，從綜合的柴油發動機或者兩個的結合。
   c) 負荷是在 UPS 的額定值內。
3) 支路模式(Bypass Mode)： 當 UPS 取得的工作模式是透過支路提供給負荷時。

- UPS 輸入從屬性特性區分:

1) Voltage and Frequency Dependent (VFD):
電壓和頻率依靠的(VFD)：能保護負荷免受電力停機。(VFD UPS 的輸出是取決於 AC 輸入電壓和頻率方面的變化並且沒被打算提供另外的修正的功能， 像那些起因於使用抽頭變壓器) 。

2) Voltage Independent (VI):
電壓獨立的(VI)：保護負荷要求如上面 VFD，和額外的： a) 在電壓下持

續提供給輸入 b) 過電壓持續提供給輸入。一輸出電壓誤差範圍窄於輸入電壓應該被製造商定義 (VI UPS 的輸出是取決於 AC 輸入頻率和 輸出電壓應該維持在規定電壓內(提供另外的修正的電壓功能，例如那些起因於使用主動和/或被動的電路) 。

3) Voltage and Frequency Independent (VFI):
電壓和頻率獨立的(VFI)：獨立的與電壓和頻率變化和保護負荷以防止這樣的變化而不會消耗被儲存的能源。

- **UPS 的效率要求:**

1) AC 輸出的 UPS
單一正常模式的 UPSs:
EffAVG (Average loading-adjusted efficiency), 計算公式請參考 Equation 1, 計算後的效率值必須大於或等於 Table 2 的最小平均效率要求值. (如果 UPS 輸出大於 10kW 且有通訊及量測能力的, 請參考 Table 3)

Equation 1: Calculation of Average Efficiency for Ac-output UPSs

$$Eff_{AVG} = t_{25\%} \times Eff|_{25\%} + t_{50\%} \times Eff|_{50\%} + t_{75\%} \times Eff|_{75\%} + t_{100\%} \times Eff|_{100\%}$$

Where:

- *Eff_{AVG} is the average loading-adjusted efficiency,*
- *$t_{n\%}$ is the proportion of time spent at the particular n% of the Reference Test Load, as specified in the loading assumptions in Table 1, and*
- *$Eff|_{n\%}$ is the efficiency at the particular n% of the Reference Test Load, as measured according to the ENERGY STAR Test Method.*

Table 1: Ac-output UPS Loading Assumptions for Calculating Average Efficiency

Output Power, P, in kilowatts (kW)	Input Dependence	Proportion of Time Spent at Specified Proportion of Reference Test Load, $t_{n\%}$			
		25%	50%	75%	100%
P ≤ 1.5 kW	VFD	0.2	0.2	0.3	0.3
	VI or VFI	0	0.3	0.4	0.3
1.5 kW < P ≤ 10 kW	VFD, VI, or VFI	0	0.3	0.4	0.3
P > 10 kW	VFD, VI, or VFI	0.25	0.50	0.25	0

Table 2: Ac-output UPS Minimum Average Efficiency Requirement

Minimum Average Efficiency Requirement ($Eff_{AVG\ MIN}$), Where: • P is the Rated Output Power in watts (W), and • ln is the natural logarithm.			
	Input Dependency Characteristic		
Rated Output Power	VFD	VI	VFI
P ≤ 1500 W	0.967		$0.0099 \times \ln(P) + 0.815$
1500 W < P ≤ 10,000 W	0.970	0.967	
P > 10,000 W	0.970	0.950	$0.0099 \times \ln(P) + 0.805$

Table 3: Ac-output UPS Minimum Average Efficiency Requirement for Products with Metering and Communications Capability

Minimum Average Efficiency Requirement ($Eff_{AVG\ MIN}$), Where: • P is the Rated Output Power in watts (W), and • ln is the natural logarithm.			
	Input Dependency Characteristic		
Rated Output Power	VFD	VI	VFI
P > 10,000 W	0.960	0.940	$0.0099 \times \ln(P) + 0.795$

2) DC 輸出的 UPS

單一正常模式的 UPSs:

EffAVG (Average loading-adjusted efficiency), 計算公式請參考 Equation 3, 計算後的效率值必須大於或等於 Table 4 的最小平均效率要求值. (如果 UPS 輸出大於 10kW 且有通訊及量測能力的, 請參考 Table 5)

Equation 3: Calculation of Average Efficiency for All Dc-output UPSs

$$Eff_{AVG} = \frac{Eff|_{30\%} + Eff|_{40\%} + Eff|_{50\%} + Eff|_{60\%} + Eff|_{70\%} + Eff|_{80\%}}{6}$$

Table 4: Dc-output UPS/Rectifier Minimum Average Efficiency Requirement

Minimum Average Efficiency Requirement (Eff_{AVG_MIN})
0.955

Table 5: Dc-output UPS/Rectifier Minimum Average Efficiency Requirement for Products with Metering and Communications Capability

Rated Output Power	Minimum Average Efficiency Requirement (Eff_{AVG_MIN})
P > 10,000 W	0.945

- UPS 的功率因素要求:

功率因素在額定全載條件下，必須符合大於 Table 6 中的最小值, Table 6 適用於所有的 VFI 和 VI 正常模式下的合格要求。

Table 6: UPS Minimum Input Power Factor Requirement

Minimum Power Factor Requirement
0.90

- UPS 的效率測試進行注意事項:

UPS 有儲存能量系統時:

1) 如果這儲存能量系統是能夠在維護正常操作模式條件下，藉著物理性或定義的控制件斷脫離時，而且在使用手冊或任何公告的文件中沒有建議不要斷開時，這 UPS 必須將儲存能量系統先斷開，在進行測試。
2) 當可能斷開儲存能量系統時, UPS 可以進行調整，以禁止任何警報，指示器，或定義的檢測機制控制在 UPS 本身或軟體上,
3) 當不能夠斷開時，測試期間，這儲存能量系統應該儲存最大能量且從儲存能量系統轉換出能量到 UPS 要最小。

- UPS 的效率測試說明:

量測效率需為穩定狀態下的值，其定義如下:

UPS 和負載必須能夠滿足長時間運轉直到溫度穩定。允許 UPS 穩定平衡的時間需大於廠商規格的 125%，如標準 Appendix J of IEC 620403, Ed. 2.0 中的指示。

在每個負載點，其溫度穩定期間中的最後 20 分鐘區間，量測出不同時間點的效率差百分比必須小於 1%，計算式如 Equation:

Equation 3: Calculation of Efficiency Variation for Determination of Steady-state

$$Percent\ Difference = \frac{|Eff_1 - Eff_2|}{Average(Eff_1, Eff_2)}$$

為了計算效率，而同時量測輸入和輸出功率量測必須依循標準 Section J.3 of IEC standard 620403, Ed. 2.0 的要求，除了以下例外項目。

1) UPS 必須測試在以下所有的負載條件:
   a) AC 輸出 UPS: 100%, 75%, 50%, 25%, and 0% of the rated output power.
   b) DC 輸出 UPS: 80%, 70%, 60%, 50%, 40%, 30%, 0% of the rated output power.

Note: 在 0% 的負載條件 (i.e., 測試負載為斷開，但輸出轉換運轉)，只量測 UPS 的數入。

以上測試在每個負載條件，量測總輸入及輸出的能量在 Wh，量測期間需大於 15 分鐘，這總能量累積率至少 1 Hz. 計算 UPS 的平均輸入功率及輸出功率，請使用 Equation 1，效率請使用 Equation 2。

Equation 1: Calculation of Average Power

$$P_{AVG} = \frac{E_{TOT}}{t}$$

Where:

- P_{AVG} *is the average power in watts.*
- E_{TOT} *is the total energy in watt-hours.*
- *t is the length of the measurement in hours.*

Equation 2: Calculation of Efficiency

$$Eff = \frac{P_{AVG\_OUT}}{P_{AVG\_IN}}$$

Where:

- *Eff is the UPS efficiency.*
- P_{AVG_OUT} *is the average output power in watts.*
- P_{AVG_IN} *is the average input power in watts.*

- **效率量測步驟:**

1) 同時量測 UPS 的累積輸入和輸出能量在瓦特-小時(Wh), 至少 5 分鐘。
2) 使用 Equation 1, 計算 UPS 的平均輸入和輸出功率在瓦特 (W)。
3) 使用 Equation 2, 計算 UPS 的效率值 Eff1.
4) 等待最少 10 分鐘。
5) 重覆步驟 1 到 3, 計算得到另一個效率值, Eff2。
6) 當 Eff1 和 Eff2 差異百分比小於 1%, 使用 Equation 3 計算,此效率值即是在 UPS 穩定狀態時的值, 可記錄此值。
7) 當 Eff1 和 Eff2 差異百分比大於或等於 1%, 使用 Equation 3 計算, 此此效率值即不是在 UPS 穩定狀態時的值. 須重覆步驟 4 到 6, 直到符合步驟 6, 才可記錄此值。

測式記錄表格如下:

a)

ENERGY STAR® UPS Test Reporting Template - Test Equipment Information				
Equipment Type	Manufacturer	Model Number	Serial Number	Calibration Due Date

b)

ENERGY STAR® UPS Test Reporting Template: Ac-output UPS Information

Laboratory Information		
Laboratory Name		
Contact Name		
Phone Number		
Fax Number		
Mailing Address		
Email Address		
Date of Agreement Between Laboratory and Manufacturing Partner		
Date Sample Testing Began		
Date Sample Testing Completed		

Test Conditions		
Ambient Room Temperature		℃
Ambient Relative Humidity		%

Test Equipment Information		
Meter Manufacturer and Model #		
Ac Line Voltage Source Manufacturer and Model #		
Other		

Unit Under Test General Information		
Manufacturer		
Single-configuration UPS/Modular UPS Minimum Configuration - Model Name		
Single-configuration UPS/Modular UPS Minimum Configuration - Mode Number		
Modular UPS Maximum Configuration - Model Name		
Modular UPS Maximum Configuration - Model Number		
Modular UPS Intermediate Configuration(s) - Model Name(s)		
Modular UPS Intermediate Configuration(s) - Model Number(s)		
Serial Number		
Production Date		
Tested Input Voltage (per Table 1 of ENERGY STAR Test Method)		V
Tested Input Frequency (per Table 1 of ENERGY STAR Test Method)		Hz
Tested Output Voltage		V
Tested Output Frequency		Hz

Unit Under Test Configuration		
Dimensions - height		mm
Dimensions - width		mm
Dimensions - depth		mm
Single-normal-mode UPS or Multiple-normal-mode UPS?		
Firmware Revision and Configuration Number		
Redundancy as Tested (N, N+1, N+N, etc.)		
Non-standard Unit Configuration Information		
Manufacturer-provided Testing Guidance		

Energy Storage Device		
Tested with internal energy storage system connected?[1] (Y/N)		
Internal energy storage system make(s)/model(s)		
Internal energy storage technology/chemistry		
Internal energy storage system capacity		Wh

[1] The UPS may be adjusted to disable any alarms, indications, or default detection mechanisms that may result from disconnecting the energy storage system, as long as the controls necessary to do so are natively present on the UPS or are included in end user software.

c)

ENERGY STAR® UPS Test Reporting Template: Ac-output UPS Measurements

Non-modular and Modular UPS			
	Representative Models Under Test [2]		
	Single-configuration UPS/ Modular UPS Minimum Configuration	UPS Maximum Configuration (Modular UPS only)	
Rated Maximum Apparent Output Power			VA
Rated Maximum Real Output Power			W

[2] For Modular UPSs, the minimum and maximum configurations are tested. All intermediate configurations qualifying for ENERGY STAR are listed in previous "Unit Under Test General Information" section. All other UPSs report data for a single configuration.

ENERGY STAR Efficiency Values - Single-normal-mode or Multiple-normal-mode (Lowest Input Dependency[3])			
	Representative Models Under Test		
	Single-configuration UPS/ Modular UPS Minimum Configuration	UPS Maximum Configuration (Modular UPS only)	
Input Dependency of Normal Mode(s) Tested (VFD, VI, or VFI[4]			
Manufacturer-specified Stabilization Time			minutes
Input Power Factor at 100% Load			
Measured 15 Minute Average Real Output Power at 100% Load			W
Eff_1 Calculation (5.B.3)			%
Eff_2 Calculation (5.B.5)			%
% Difference Between Eff_1 and Eff_2 (5.B.6)			%
15 Minute Efficiency Calculation at 100% Load			%
Measured 15 Minute Average Real Output Power at 75% Load			W
Eff_1 Calculation (5.B.3)			%
Eff_2 Calculation (5.B.5)			%
% Difference Between Eff_1 and Eff_2 (5.B.6)			%
15 Minute Efficiency Calculation at 75% Load			%
Measured 15 Minute Average Real Output Power at 50% Load			W
Eff_1 Calculation (5.B.3)			%
Eff_2 Calculation (5.B.5)			%
% Difference Between Eff_1 and Eff_2 (5.B.6)			%
15 Minute Efficiency Calculation at 50% Load			%
Measured 15 Minute Average Real Output Power at 25% Load			W
Eff_1 Calculation (5.B.3)			%
Eff_2 Calculation (5.B.5)			%
% Difference Between Eff_1 and Eff_2 (5.B.6)			%
15 Minute Efficiency Calculation at 25% Load			%
Measured 15 Minute Average Real Input Power at 0% Load			W

ENERGY STAR Efficiency Values - Multiple-normal-mode only (Highest Input Dependency)			
	Single-configuration UPS/ Modular UPS Minimum Configuration	UPS Maximum Configuration (Modular UPS only)	
Input Dependency of Normal Mode(s) Tested (VFI, VI, or VFD)			
Manufacturer-specified Stabilization Time			minutes
Input Power Factor at 100% Load			
Measured 15 Minute Average Real Output Power at 100% Load			W
Eff_1 Calculation (5.B.3)			%
Eff_2 Calculation (5.B.5)			%
% Difference Between Eff_1 and Eff_2 (5.B.6)			%
15 Minute Efficiency Calculation at 100% Load			%
Measured 15 Minute Average Real Output Power at 75% Load			W
Eff_1 Calculation (5.B.3)			%
Eff_2 Calculation (5.B.5)			%
% Difference Between Eff_1 and Eff_2 (5.B.6)			%
15 Minute Efficiency Calculation at 75% Load			%
Measured 15 Minute Average Real Output Power at 50% Load			W
Eff_1 Calculation (5.B.3)			%
Eff_2 Calculation (5.B.5)			%
% Difference Between Eff_1 and Eff_2 (5.B.6)			%
15 Minute Efficiency Calculation at 50% Load			%
Measured 15 Minute Average Real Output Power at 25% Load			W
Eff_1 Calculation (5.B.3)			%
Eff_2 Calculation (5.B.5)			%
% Difference Between Eff_1 and Eff_2 (5.B.6)			%
15 Minute Efficiency Calculation at 25% Load			%
Measured 15 Minute Average Real Input Power at 0% Load			W

[3] The unit is tested in the highest efficiency sub-mode of each tested normal mode.

[4] VFD: Voltage and Frequency Dependent; VI: Voltage Independent; VFI: Voltage and Frequency Independent

d)

ENERGY STAR® UPS Test Reporting Template: Dc-output UPS Information

Laboratory Information		
Laboratory Name		
Contact Name		
Phone Number		
Fax Number		
Mailing Address		
Email Address		
Date of Agreement Between Laboratory and Manufacturing Partner		
Date Sample Testing Began		
Date Sample Testing Completed		

Test Conditions		
Ambient Room Temperature		℃
Ambient Relative Humidity		%

Test Equipment Information		
Meter Manufacturer and Model #		
Ac Line Voltage Source Manufacturer and Model #		
Other		

Unit Under Test General Information		
Manufacturer		
Model Name		
Ac-output UPS System Model Number(s)		
Serial Number		
Rectifier Module Model Number		
Production Date		
Tested Input Voltage (per Table 1 of ENERGY STAR Test Method)		V ac
Tested Input Frequency (per Table 1 of ENERGY STAR Test Method)		Hz
Tested Output Voltage		V dc

Unit Under Test Configuration		
Dimensions - height		mm
Dimensions - width		mm
Dimensions - depth		mm
Firmware Revision and Configuration Number		
Manufacturer-provided Unit Configuration Information		
Manufacturer-provided Testing Guidance		

Energy Storage Device		
Tested with internal energy storage system connected?[5] (Y/N)		
Internal energy storage system make(s)/model(s)		
Internal energy storage technology/chemistry		
Internal energy storage system capacity		Wh

[5] The UPS may be adjusted to disable any alarms, indications, or default detection mechanisms that may result from disconnecting the energy storage system, as long as the controls necessary to do so are natively present on the UPS or are included in end user software.

ENERGY STAR® UPS Test Reporting Template: Dc-output UPS Measurements

Specifications				
		Dc-output UPS System Representative Models Under Test[6]		
		Single-configuration UPS/ Modular UPS Minimum Configuration	UPS Maximum Configuration (Modular UPS only)	
Rated Maximum Real Output Power				W

[6] For Modular Dc-output UPS Systems, the minimum and maximum configurations are tested. All intermediate configurations qualifying for ENERGY STAR are listed in a later section. All other UPSs report data for a single configuration.

ENERGY STAR Efficiency Values				
	System Rectifier Module	Dc-output UPS System Representative Models Under Test		
		Single-configuration UPS/ Modular UPS Minimum Configuration	UPS Maximum Configuration (Modular UPS only)	
ENERGY STAR weighted calculation of average efficiency				%
Manufacturer-specified Stabilization Time				minutes
Input Power Factor at 100% Load				
Measured 15 Minute Average Real Output Power at 80% Load				W
Eff_1 Calculation (5.B.3)				%
Eff_2 Calculation (5.B.5)				%
% Difference Between Eff_1 and Eff_2 (5.B.6)				%
15 Minute Efficiency Calculation at 80% Load				%
Measured 15 Minute Average Real Output Power at 70% Load				W
Eff_1 Calculation (5.B.3)				%
Eff_2 Calculation (5.B.5)				%
% Difference Between Eff_1 and Eff_2 (5.B.6)				%
15 Minute Efficiency Calculation at 70% Load				%
Measured 15 Minute Average Real Output Power at 60% Load				W
Eff_1 Calculation (5.B.3)				%
Eff_2 Calculation (5.B.5)				%
% Difference Between Eff_1 and Eff_2 (5.B.6)				%
15 Minute Efficiency Calculation at 60% Load				%
Measured 15 Minute Average Real Output Power at 50% Load				W
Eff_1 Calculation (5.B.3)				%
Eff_2 Calculation (5.B.5)				%
% Difference Between Eff_1 and Eff_2 (5.B.6)				%
15 Minute Efficiency Calculation at 50% Load				%
Measured 15 Minute Average Real Output Power at 40% Load				W
Eff_1 Calculation (5.B.3)				%
Eff_2 Calculation (5.B.5)				%
% Difference Between Eff_1 and Eff_2 (5.B.6)				%
15 Minute Efficiency Calculation at 40% Load				%
Measured 15 Minute Average Real Output Power at 30% Load				W
Eff_1 Calculation (5.B.3)				%
Eff_2 Calculation (5.B.5)				%
% Difference Between Eff_1 and Eff_2 (5.B.6)				%
15 Minute Efficiency Calculation at 30% Load				%
Measured 15 Minute Average Real Input Power at 0% Load				W

以上資料參考來源:

US ENERGY STAR website at

http://www.energystar.gov/index.cfm?c=new_specs.uninterruptible_power_supplies